The Astronomical Society of the Pacific (ASP) is pleased to announce its 128th Annual Meeting will be a special STEM outreach conference focused on preparations for the 2017 solar eclipse that will be visible across North America.

Please save the dates **December 8-9, 2016**, and join us at the Moonrise Hotel in **St. Louis, Missouri**, for this conference titled: “Engage Every Child in the 2017 Solar Eclipse: Working Together with Diverse and Underserved Communities Across America.”

The vast majority of the population in North America will experience a spectacular partial solar eclipse in their hometowns and could participate in eclipse events at venues such as schools, local parks, libraries, and other sites in their neighborhoods. This conference will concentrate on the task of ensuring broad participation in the August 21, 2017, solar eclipse, especially among diverse and underserved communities off the eclipse’s path of totality.

**The goals of the conference** are to (a) convene a mix of outreach-minded scientists, educators, and eclipse enthusiasts together with STEM community leaders interested in fostering diverse engagement in the 2017 eclipse, and (b) offer a program featuring helpful strategies, information, resources, networking opportunities, and personal connections to enable people to follow-up and plan for successful eclipse engagement with underserved communities in their own regions.

Space will be limited for this conference. There will be contributed poster presentations and a select number of workshops, talks, and panels. Further details on the conference will be announced in coming weeks. In the meantime, please mark your calendar and **sign up to add your name and email to the conference’s interest list** (with no obligations). Doing so will ensure you receive further information as it becomes available.
Reflections on a Journey to Totality
LINDA SHORE
My trip to Indonesia gave me much more than a total eclipse of the Sun.

A Totality 2017 Eclipse Workshop
EDITED BY PAUL DEANS

The Eclipse, The Media, and Being Outside the Path
JOE RAO
Don’t fret. Eclipse 2017 will ultimately be the media event of the season.

Astronomy in the News
A seasonal dust storm pattern on Mars, an unexpected excess of giant planets in a star cluster, and the universe apparently expanding faster than expected. These are some of the discoveries that recently made news in the astronomical community.

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on the cover
Front: Galaxy NGC 7714 resembles a partial golden ring from an amusement park ride. This unusual structure is a river of Sun-like stars that has been pulled deep into space by the gravitational tug of a passing galaxy. Courtesy NASA/ESA.
Back: This new HST image shows the heart of the Crab Nebula including the central neutron star — it’s the rightmost of the two bright stars right of center. More details about this image, plus a zoomable version of the image, are here. Courtesy NASA/ESA.
August 21, 2017: It’s Not Just About Totality

It's always interesting (to me, at least) how issues of Mercury sometimes come together in unexpected ways. When I started working on this issue, I didn't expect it to be so solar-eclipse heavy — it just seemed to organically evolve that way.

I was expecting Linda Shore's excellent piece (page 17) about her trip to Indonesia for the March 2016 solar eclipse. Then I came across Joe Rao's response (page 33) to a number of rants about the lack of media coverage for the 2017 eclipse. "Come on, people," I thought, "It's more than a year away; the media doesn't work that way." Joe said it much better.

But he also brought up a topic that concerns the ASP. If you read the "Totality 2017 Eclipse Workshop" piece starting on page 25, you'll eventually come to Michael Zeiler’s analysis of how many people actually live in the path of totality. It’s an impressive number (yes, you have to go and look for yourself), but many more live many hundreds of miles away.

Of course great numbers will make their way to totality, but far greater numbers won't for a variety of reasons. Many of those who will miss out on totality are children. And yet, with just a little help, they can still have a satisfying and educational non-totality experience.

With this in mind, the ASP is planning its upcoming annual meeting around the theme “Engage Every Child in the 2017 Solar Eclipse: Working Together with Diverse and Underserved Communities Across America.” This conference will concentrate on the task of ensuring broad participation in the August 21, 2017, solar eclipse, especially among diverse and underserved communities away from the path of totality.

If you missed the announcement for this on page 2, go back, click on the link, sign up for more details, and consider joining us in St. Louis on December 8 and 9 for this very important STEM outreach conference.

Paul Deans
Editor, Mercury
Many ancient civilizations associated eclipses with horrible omens, death, disease, and the like, so it’s not surprising the rulers of these civilizations were heavily invested in predicting these eclipses accurately. Babylonian kings were especially interested in eclipse prediction, since a solar eclipse meant something really awful was in store for whatever king was in power. The solution? Put a temporary king on the throne on the day of the solar eclipse, and let him deal with the bad fortune. Then take back your crown.

It was Babylonian scholars who discovered the Saros Cycle, the 18-year 11-day period between solar eclipses sharing the same time of year, with the Moon, Earth, and Sun having the same geometry in space. Predicting total solar eclipses was critical and, in many ways, the birth of modern astronomy can be traced to ancient astronomers who charted the path of the Sun and Moon so future solar eclipses could be announced accurately ahead of time. But get the date wrong, and a ruler might just order the executioner to remove your head. Not even in today’s “publish or perish” world of academia is precision of such important to the health and well being of an astronomer!

Total solar eclipses are awesome, transformative, not-to-be missed events. Witnessing a total solar eclipse should certainly be on the bucket list of every professional, amateur, and casual astronomy enthusiast. But if you want to see one, you had better get your ducks a row and book your travel quickly because seats and hotel rooms are limited. You had also better find a highly reputable eclipse touring company with years upon years of previous experience, because if you don’t you run the risk of….


Let’s be honest. As historically important and awe inspiring as total solar eclipses are, it is a royal pain in the neck to see one. Paths of totality generally cross remote locations difficult to I’m watching the partial phases of the recent eclipse with my safe solar viewers. [ASP]

In The Path of Totality
Traveling to totality can be a royal pain… except in 2017.
get to, and the weather along the path of totality is likely to be horrible, so your chance of witnessing the full glory of the eclipse can be small. When an eclipse does occur somewhere where the weather will likely cooperate and is accessible by transportation (often a complex combinations of planes, trains, and automobiles), it’s usually phenomenally expensive. Total eclipses don’t generally happen in areas served by major airports. Be prepared instead for a long and expensive airline flight to very remote part of the world.

You also need to have time, and lots of it. Getting to the path of totality can take as long as a week, so if you have work or family obligations, witnessing a total solar eclipse somewhere in the Atacama Desert, on a remote island in the Pacific, or from the Mongolian Plateau might not be in the cards. Solar eclipse chasing as a hobby is somewhat restricted to those with the fortunate combination of time and money.

The inaccessibility of the vast majority of solar eclipses is what makes the Great American Eclipse of 2017 so significant. For the first time since February 26, 1979, a total solar eclipse will be visible in the continental US, and for the first time since June 8, 1918, the path of totality will extend from coast to coast.

On August 21, 2017, the total solar eclipse will begin at about 10:17 am local time along the Oregon coast; the last people to witness totality will be on the coast of South Carolina 1 hour and 30 minutes later, or roughly 2:47 pm local time. An estimated 12 million people live within the path of totality, but many millions more will probably travel to the path to witness this spectacular event.

Advance planning to educate people about the 2017 solar eclipse has begun in earnest. The American Astronomical Society (AAS) has convened four major workshops that gathered astronomers and astronomy educators together to coordinate efforts and ensure the best ideas for engaging the public are disseminated widely (see page 25). The AAS is taking on many issues including how to spread the world about the eclipse across the country, and how to tackle the gnarly problem of promoting eye safety without frightening people into staying indoors with the blinds drawn and watching it on TV.

The ASP is working closely with the AAS to ensure as many people as possible enjoy the 2017 Great American Solar Eclipse. *We have decided to focus our attention on those who will experience the partial eclipse, and especially on children of poverty living in large urban centers who do not have the means to travel to witness totality.* The ASP wants to make sure that these traditionally underserved children fully experience this once-in-a-lifetime astronomical event.

To that end, the ASP is currently planning a workshop of its own, which will bring together solar eclipse experts, astronomy education outreach specialists, and STEM leaders working with underserved communities to develop programs for children and their families (page 2). We will make sure no child is left out from experiencing this historic eclipse.

In this issue of *Mercury*, I describe my own personal journey to the March 2016 Indonesian eclipse. It was my very first experience with totality, and as an “total eclipse naïf,” I depict what it was like to prepare for the long journey, to be in the company of experienced solar eclipse chasers, and to witness the solar eclipse with about a thousand local Indonesians.

Did witnessing the wonder of totality change my life? Did I think the long journey across the world was worth it for the two minutes of coronal joy I experienced? You’ll have to read the article (page 17) to find out.  

**LINDA SHORE** is the Executive Director of the Astronomical Society of the Pacific.
Of Moonbows, Rainbows, and Marco Antonio de Dominis

The man who first explained rainbows was not Isaac Newton.

It is said Aristotle only observed a certain lunar phenomenon twice in 50 years, and most people today have never seen it — the elusive moonbow. An account by an unknown observer from Christmas Day 1710, as described in the *Philosophical Transactions of the Royal Society of London* (1711), testifies to its unique beauty. At the time the Moon was just 24 hours past full, and the evening had been rainy, but when the clouds dispersed and the Moon shone around 8:00 pm, the viewer was treated to a spectacle over the English countryside of Derbyshire.

“The iris was more remarkable than that which Dr. Plot observed at Oxford, the 23d of November 1675; that being only of a white color, but this had all the colors of the solar iris, only faint in comparison with those we see in the day.”

The observer was puzzled by the largeness of the arc, which was not much less than that of an arc produced by the Sun. He thought the smaller physical dimension of the Moon and its closeness to Earth would have resulted in a smaller arc. “But as to its entireness and beauty of its color, it was surprising.” The moonbow lasted some 10 minutes before a cloud put an end to the show.

If you check Wikipedia, you will see only two historical mentions of lunar rainbows: Aristotle, and a passing mention of one in a publication of 1847. I highlight it to show not only that such historical instances are rare, but the literature on them is also far from rigorously inclusive, since the 1675 and 1710 instances are not included. Moonbows have featured in poetry, but again rarely. In 1825, for example, the British dramatist David Arnott described, “the radiance of the moon-bow’s purpling hues.”

As for rainbows, Isaac Newton attributed knowledge of what caused that phenomena to the Croatian prelate Marco Antonio de Dominis. Newton wrote in *Opticks*: “...it is now agreed upon, that this Bow is made by Refraction of the Sun’s Light in drops of falling Rain. This was understood by some of the Antients, and of late more fully discover’d and explained by the famous Antonius de Dominis.”

The man Newton mentions so enraged the Catholic church that upon his death in 1624 his body, surrounded by his books, were burnt in Rome’s Campo dei Fiori. This era witnessed a reign of terror waged by the Church — 24 years earlier the great thinker Giordano
Bruno was burned at the stake, while nine years after the death of Dominis, Galileo was put on trial and lost his freedom.

A look at the title page of Dominis' 1611 book, *Tractatus de radiis visus et lucis in vitris*, is informative. Dominating the page is an image known as a printer's mark. It is the same mark used just one year earlier on Galileo's book *Sidereus Nuncius* which contains the first astronomical observations made with a telescope. The mark's Latin inscription reads 'From Here True Religion.'

Another similarity is what is printed below that: Apud Thomam Baglionum. It was believed Thomas Baglioni was the publisher of Galileo's book, but a study in 2014 by Nick Wilding at Georgia State University shows that is not true. Baglioni did not have a press at that time; he actually used the press of Niccolò Polo, who may have published Dominis' book as well.

So much is intertwined, and yet another fascinating link is Giovanni Bartoli, named on the title page of Dominis' book as the editor. Bartoli is a key source for our knowledge of the origins of the telescope in Venice. In October 1609, Bartoli bought a French-made telescope for the Medici rulers of Florence.

On March 27, 1610, Bartoli wrote to a friend that Galileo's book was being “read by everyone” in Venice. “With his spyglass,” Bartoli wrote, Galileo “has found four other planets and seen another world on the Moon, and similar things that provide pleasant food for thought to the professors of those sciences.” Food for thought indeed!

DR. CLIFFORD CUNNINGHAM was recently seen chatting with His Excellency Bruce Heyman, the US ambassador to Canada.

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### Solar Eclipse 2017 and Citizen Science

*Three projects aim to engage groups and individual observers in scientific data collection during the eclipse of 2017.*

Solar eclipses are awe-inspiring phenomena and make great public outreach events. There is also some real [scientific value](#) to these events, particularly along the path of totality. For example, eclipses offer a unique opportunity to study Earth's atmosphere, particularly the [ionosphere](#). Furthermore, the solar radius can be determined using a fixed geometric reference — the Moon's diameter — and such measurements can be used to monitor changes in the Sun's diameter. Finally, ground-based solar eclipse observations also provide a useful comparison to space-based measurements.

You might think coronagraphs would make total solar eclipse observations obsolete, but this is not the case. Non-eclipse measurements with coronagraphs suffer from sunlight scattered in the Earth's atmosphere and stray light that scatters within the instrument. Space-based coronagraphs can't view the corona down to the photosphere. Total solar eclipses, on the other hand, minimize both of these [effects](#), allowing the best possible views of the inner corona.
So, solar eclipses provide data that are not accessible even to space-based coronagraphs.

Imagine the amazing data that could be obtained by an army of ground-based observers, using a consistent set of instrumentation and protocols, stationed along the path of a total solar eclipse. That is exactly what three citizen science projects hope to achieve during the solar eclipse on August 21, 2017. These three projects are the “Eclipse Megamovie Project,” “Citizen CATE,” and the “Eclipse Ballooning Project.”

**Eclipse Megamovie Project**
The duration of totality is approximately two minutes for an individual observer at a given location. However, if multiple observers spread across the eclipse path take a few images each, these can be “stitched” together to create a 90-minute movie. The more pictures acquired, the longer the movie. If a million pictures are acquired, say 100 or so from 1000 observers, the project could produce a 12-hour, slow motion movie of the eclipse! The Eclipse Megamovie Project plans to produce just such a time-resolution movie of the 2017 solar eclipse.

First proposed in a 2011 “white paper,” the Eclipse Megamovie is expected to go beyond education and public outreach — it should provide valuable scientific data on the inner corona. It even might be possible to use the movie to “recreate” Arthur Eddington’s famous 1919 test of general relativity, using CCDs! The founders of the Eclipse Megamovie Project were able to create a movie of the 2012 annular solar eclipse in Australia, and the results are posted on their Facebook page. The creation of this movie from a variety of imaging systems required the development of specialized software.

Unlike the other two projects mentioned below that already have established observing teams, the Eclipse Megamovie Project is still recruiting participants. Their website states that the summer of 2016 will mark the start of an education and public outreach tour along the eclipse path. They will hold community forums and town-hall meetings — so, if you live in or near the path of totality and are interested in participating, keep an eye out for them!

**Citizen CATE**
The Citizen CATE project also aims to produce a continuous 90-minute movie of the solar corona. The ultimate scientific goal of this project is an improved understanding of the time evolution of the inner corona; this includes studies of rarely seen solar phenomena such as plasmoids and recently discovered magnetic bubbles. They expect to have observers at 61 locations along the path of totality in the continental United States. Each observing team will acquire white-light images of the corona during the totality phase with the image centered on the Sun.

All Citizen CATE volunteers will be provided (free of charge) with the same off-the-shelf hardware: telescope, mount, CCD imaging system, neutral density filter, computer, and control software. Volunteers will be trained to use the equipment and are expected to be familiar with their observation site. After the experiment is concluded, they will upload their images, and they (hopefully) get...
to keep their equipment. They will have access to all data collected from the experiment and will be cited on all scientific papers as well. Currently, there are 59 committed volunteers.

**Eclipse Ballooning Project**

The Eclipse Ballooning Project is spearheaded by NASA’s National Space Grant College and Fellowship Program and Montana State University. This project will stream live video and images of the total eclipse from near space along the path of totality. All teams will be provided with a common camera and tracking payload. In addition, teams get to choose a second payload for their balloon.

Student teams will build all instrumentation from a kit, choose their launch site (keeping in mind that they need to avoid restricted airspaces), and be able to recover their balloon (so they have to be aware of landing terrain and land status). Groups involved in the project are spending anywhere from $6,000 to $25,000 to cover equipment and travel costs to workshops and launch and recovery sites.

Fortunately, teams composed of all undergraduate students can apply to their state Space Grant Program to cover all or part of their funding. In conjunction with this project, some 150 universities and pre-college programs are launching radiosonde balloons during the eclipse to collect atmospheric data such as temperature, pressure, and ozone fluctuations.

**JENNIFER BIRRIEL** is Professor of Physics in the Department of Mathematics & Physics at Morehead State University in KY. She hopes to observe the eclipse from western Kentucky.

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**Jovian Encounters**

*Juno is the ninth spacecraft to visit Jupiter.*

The largest planet in our solar system just received a visitor. Juno, a NASA probe launched in 2011, entered Jovian orbit on July 4. We have sent more probes to Jupiter than any other planet, with seven flybys and one orbiter since 1973.

The first callers were the Pioneer probes, with Pioneer 10’s closest approach in 1973 and Pioneer 11 the following year. Pioneer 10 took the first space-based images of Jupiter and its moons, but ran smack into the plague of all future missions: Jupiter’s intense radiation belts, the result of a complicated interaction between Jupiter’s magnetic field, several of its moons, and the solar wind. They’re devastating to electronics (humans, too, but that hasn’t been a problem yet). We knew about the belts from ground-based observations, but they were 10 times stronger than expected.

Voyagers 1 and 2 followed, with their closest approaches in March and July of 1979. They took the first high-resolution images of Jupiter’s atmosphere, and established that the Great Red Spot, the
centuries-old splotch three times Earth’s diameter, was a monstrous storm. The Voyagers also revealed much about Jupiter’s satellites, including observing nine volcanic eruptions on Io — the first ever seen on a world other than Earth.

Jupiter’s immense size makes it ideal for gravity assists, trajectory maneuvers that spacecraft use to alter their course without having to expend fuel. The three Jovian flybys after Voyager 2 were primarily for this boost — with incidental groundbreaking science. Ulysses needed to escape the plane of the solar system to complete its mission (studying the Sun), and while getting a push from Jupiter in 1992 (and again in 2004), it turned its radio and particle detectors on the gas giant. Cassini (to Saturn) and New Horizons (to Pluto) swung by in 2000 and 2007, respectively, for assists en route to their final destinations. Cassini’s pictures are actually the best we have of Jupiter — color images with 60 km resolution. New Horizons used its Jovian flyby as a dress rehearsal for its Pluto mission, studying Jupiter’s faint, distant moons as it passed by.

The first Jupiter orbiter was Galileo. Launched in 1989, it reached orbit in 1995. However, its largest antenna did not deploy properly after launch, reducing by an order of magnitude the amount of data it could send back to Earth. Once at Jupiter, things got even worse. The tape recorder (yes, a tape recorder) that the probe used to store data was badly damaged by radiation, the on-board gyroscopes and oscillators were affected, and there were electrical arcs between pieces of the spacecraft, repeatedly sending the probe into “safe” mode.

Despite these difficulties, Galileo gathered great data. Upon arrival it released a small probe into the atmosphere of the gas giant, which transmitted for 57 minutes before melting 150 km below the cloud tops. Galileo followed up on tantalizing hints from Voyager that Europa has a subsurface water ocean, and discovered evidence for the same on Ganymede and Callisto. More was learned about Io’s volcanoes, and the magnetic and atmospheric characteristics of Jupiter were studied in greater depth. In 2003 the probe was deliberately crashed into the planet.

Juno will pick up where Galileo left off. Its main goals are to study the planet’s magnetic and gravitational fields, and gather data about the planet’s atmosphere and composition. The probe’s orbit is long and elliptical to minimize the time it spends in the radiation belts, and a “vault” with centimeter-thick titanium walls protects its sensitive electronics. Even so, its delicate camera and infrared spectrometer are expected to survive only 11 of the planned 37 orbits. After completing its mission in 2018, Juno will suffer the same fate as Galileo.

EMILY JOSEPH is a Research Assistant (with an emphasis on Mars studies) at the Planetary Science Institute, and is part-time on the VIMS operations team for the Cassini mission at the University of Arizona Lunar and Planetary Lab. You can find her on Twitter @EmExAstris.
Globulars have been summarily dismissed as a home for planets. Not so fast.

Our Milky Way galaxy hosts about 150 globular clusters, most of them orbiting in the galactic outskirts. They formed about 10 billion years ago on average. As a result, their stars contain fewer of the heavy elements needed to construct planets, since those elements (like iron and silicon) must be created in earlier generations of stars. Some scientists have argued that this makes globular cluster stars less likely to host planets.

Rosanne DiStefano (Harvard-Smithsonian Center for Astrophysics [CfA]) and her colleague Alak Ray (Tata Institute of Fundamental Research, Mumbai) argue that this view is too pessimistic. Exoplanets have been found around stars only one-tenth as metal-rich as our Sun. And while Jupiter-sized planets are found preferentially around stars containing higher levels of heavy elements, research finds that smaller, Earth-sized planets show no such preference.

“A globular cluster might be the first place in which intelligent life is identified in our galaxy,” says DiStefano. “It’s premature to say there are no planets in globular clusters,” adds Ray.

Another concern is that a globular cluster’s crowded environment would threaten any planets that do form. A neighboring star could wander too close and gravitationally disrupt a planetary system, flinging worlds into icy interstellar space.

However, a star’s habitable zone — the distance at which a planet would be warm enough for liquid water — varies depending on the star. While brighter stars have more distant habitable zones, planets orbiting dimmer stars would have to huddle much closer. Brighter stars also live shorter lives, and since globular clusters are old, those stars have died out.

The predominant stars in globular clusters are faint, long-lived red dwarfs. Any potentially habitable planets they host would orbit nearby and be relatively safe from stellar interactions.

“Once planets form, they can survive for long periods of time, even longer than the current age of the universe,” explains DiStefano.

So if habitable planets can form in globular clusters and survive for billions of years, what are the consequences for life should it evolve? Life would have ample time to become increasingly complex, and even potentially develop intelligence.

Such a civilization would enjoy a very different environment than our own. The nearest star to our solar system is four light-years, or 24 trillion miles, away. In contrast, the nearest star within a globular cluster could be about 20 times closer — just one trillion miles distant [less than one-fifth of a light-year]. This would make interstellar communication and exploration significantly easier.

“We call it the ‘globular cluster opportunity,”’ says DiStefano. “Sending a broadcast between the stars wouldn’t take any longer than a letter from the US to Europe in the 18th century. Interstellar travel would take less time too.”
Sometimes, even the world’s largest telescope needs a little boost. And when it gets it, the results are spectacular. Using the W. M. Keck Observatory, astronomers peered back to the dawn of the universe, more than 13 billion years ago, and detected a faint galaxy less than 10,000 times the mass of the Milky Way. The galaxy appears to be sort of a “missing link” between the formation of the very first stars and the era called reionization, when hydrogen transitioned from largely neutral to ionized and the universe began to resemble the structure we see today.

Normally such a galaxy wouldn’t be visible, even with Keck, the twin-telescope observatory near the summit of Mauna Kea on the island of Hawai’i that’s the largest and most powerful on Earth. But astronomers got the gift of a ‘natural’ upgrade in the form of gravitational lensing, a natural phenomenon predicted by Einstein in which the gravity of an intermediate object bends and magnifies the light passing through it from a distant object.

In this case, a galaxy cluster named MACS2129.4-0741 distorted the light from the primeval galaxy and created three magnified images: amped up by a factor of 11, 5, and 2. The astronomers used the Hubble Space Telescope to confirm that the three images were indeed emanating from the same source.

Without this natural magnification, “we would not have been able to see it,” said Kuang-Han Huang of the University of California, Davis, lead author on a paper about the discovery published in May in The Astrophysical Journal Letters. “It lies near the end of the reionization epoch, during which most of the hydrogen gas between galaxies transitioned from being mostly neutral to being mostly ionized…and lit up the stars for the first time.”

More than a trick done with mirrors, Huang said the observation demonstrates that gravitational lensing can be a tool to probe the era of reionization, previously thought to be out of reach with the current generation of world-class observatories.

Reionization marks the transition between the so-called dark ages and the rebirth of light. The universe was created in a Big Bang. But as the universe expanded and cooled, electrons stuck to hydrogen
atoms to form neutral hydrogen. This thick blanket of neutral hydrogen created a fog that obfuscated the light of what few stars might have formed. These early stars were very large and burned up quickly, exploded, and formed new stars. The heat began to ionize the neutral hydrogen, lifting the fog so to speak.

While brighter and more distant objects have been detected with the likes of the HST, no instrument has been able to see what surely must be the most common types of galaxies during this important time in the universe’s evolution: young, modest-size galaxies with no dust and simple, massive stars burning mostly hydrogen.

That’s what makes this otherwise nondescript galaxy so exciting, said Marc Kassis, staff astronomer at Keck Observatory, who helped the UC Davis-led team with the mechanics of the observation. The galaxy is only about 10 million stellar masses, which is a typical range for the galaxies thought to dominate the reionization era at about redshift 7, or when the 13.8-billion-year-old universe was only about 800 million years old. It’s a textbook example of the kind of structure predicted by theory.

NASA’s James Webb Space Telescope, now slated for a 2018 launch, has the pointed goal of probing the era of reionization. Keck plus gravitational lensing can help guide that mission. JWST plus gravitational lensing? Now that would be off-the-chart.

CHRISTOPHER WANJEK is a Baltimore-based science writer hoping to reionize his grill this summer.

It’s Elementary

Elementary teachers are particularly challenged due to their requirement to teach multiple subjects.

Recently, The National Academies Press published *Science Teachers’ Learning* (NAP, 2015), a report on the current state of science teacher preparation, along with recommendations for approaching how and when teachers engage in professional development and the changes necessary to education policy influencing those opportunities.

I became aware of this new resource at the 2016 NSTA National Conference on Science Education in Nashville, Tennessee, when Dr. Julie Luft, a member of the committee that worked on the report, gave a presentation to a joint meeting of the National Science Education Leadership Association (NSELA) and the Association for Science Teacher Education (ASTE). In her talk, Dr. Luft presented some sobering, but not surprising, statistics from the report. During a three-year period, 41% of elementary teachers did not participate in any science-related professional development (PD), and only 12% participated in the equivalent of one day of science-related PD during the same three-year period. This is in stark contrast to the 18% of middle school and 15% of high school teachers who did not engage in science-related PD, while 47% of middle school science teachers and 57% of high school teachers did participate in at least one day of
science PD per year during the same time.

Elementary teachers are challenged compared to their secondary colleagues due largely to their requirement to teach multiple subjects, particularly math and language arts, which are emphasized due to their prominence in the high-stakes testing that has influenced education policies since the implementation of No Child Left Behind.

As a result of these policies, studies cited in the NAP report indicate only 19% of K–2 classrooms, and 30% of those in grades 3–5 receive science instruction on a daily basis. When science is offered, it accounts for only an average of 19 minutes per day in grades K–3, compared to 54 minutes for math and 89 minutes per day in language arts. Grade 4–6 classes show a slight increase to 24 minutes per day for science instruction. Because of these short time spans for science, learners make few connections between the instruction and the development of a rudimentary understanding of basic scientific concepts.

Even in classrooms where science takes a greater role, elementary teachers are generally unprepared to develop learning opportunities for their students, let alone implement them. While teaching basic scientific concepts requires a different skill set and knowledge base than that required for engaging in scientific research, few teacher preparation programs provide adequate opportunities for acquiring the relevant pedagogical content knowledge. Only 5% of elementary teachers majored in a science-related field, about the same as the 6% who took no college science courses.

From time to time I visit science-methods classes in teacher preparation programs at local universities. I also have interacted with in-service elementary teachers during teacher resource fairs, and professional development workshops delivered at the Astronomical Society of the Pacific. While many of the elementary teachers I come in contact with have a relatively sophisticated understanding of science, a large number of the early elementary teachers I have spoken with demonstrate the opposite.

One first grade teacher in particular described how he incorporated the scientific method into activities, with students conducting controlled experiments. During our conversation, we discussed how the scientific method is a myth, and how there are a great many ways of doing science. Much of biology, as well as earth and space science, do not conduct controlled experiments, but rely on observation, prediction, and modeling to arrive at conclusions. A more developmentally appropriate approach for engaging a first grader involves emphasizing questioning and making observations to recognize and describe patterns. The ability to control variables is cognitively available for somewhat older learners.

A Framework for K–12 Science Education (NAP, 2012) and the subsequent Next Generation Science Standards (NAP, 2013) set the stage for significant changes in how teachers will approach their curricular and instructional decisions. Teacher preparation programs, as well as professional development providers (including the ASP) are in the process of redeveloping their offerings to reflect these changes.

The emphasis on student engagement in the practices of science and reasoning from evidence, requires a better understanding on the part of implementing teachers of both the core ideas and concepts of science and their application during active investigations through the use of the practices. The report’s implications, and efforts to fully implement the philosophy laid out in the Framework, is that science instruction in elementary grades must, and will, increase. To accomplish this, the frequency and quality of teacher learning must also change, something the ASP is well positioned to participate in.

BRIAN KRUSE manages the formal education programs at the ASP and serves as the Director for Region F of the National Science Education Leadership Association. (NSELA).
Eclipse 2017 Cartoons

A total solar eclipse occurs when the Moon aligns with the Sun. The Moon’s shadow passes over the Earth, creating an area of temporary darkness.

On August 21, 2017, a total eclipse of the Sun is coming to the USA, for the first time in a generation. The majority of Americans have no idea what is about to happen!

As the Moon moves in its orbit, its shadow traces a path of totality across the Earth’s surface. Every spot along this path sees a total eclipse.

As the Moon’s shadow passes over the land, it creates a cone of darkness that extinguishes the blue daylight sky, so that the stars become visible.

The 2017 eclipse is the first eclipse over the USA since the 1970s, and the first coast-to-coast eclipse in a century! This is unprecedented in lifetime of everyone currently alive.

The 20th century was a dark age of American eclipses, but the 21st century will be a golden age! There will be five total solar eclipses over the USA in the next 35 years! Today’s young Americans can see them all! They are... Generation Eclipse!

JAY RYAN been involved in astronomy popularization and education since 1995. His specialty is creating astronomical “cartoons,” illustrations depicting the phenomena of the Sun, Moon, stars, and planets. He intends to create one of these Eclipse 2017 cartoons every month leading up to the 2017 eclipse. They are available here, and he invites educators and other publications) to use the strip for their educational and community outreach efforts. Note that this strip is not to be reproduced in any for-sale publications without permission from the author.
Reflections on a Journey to Totality

My trip to Indonesia gave me much more than a total eclipse of the Sun.

By Linda Shore

Looking out across the landscape from Borobudur, a Buddhist temple in Indonesia. Unless otherwise stated, all images are courtesy Linda Shore.
I had been the ASP’s Executive Director for just two months when I met Melita Wade Thorpe — founder and president of MWT Tours, pioneer of astronomy themed vacations, and force of nature. Since 1984, Melita has been escorting groups of astronomy enthusiasts around the globe to marvel at the aurora borealis from Iceland, witness meteor showers from Botswana, and visit the collection of giant telescopes perched high above the Atacama Desert of Chile. She had led solar eclipse tours to just about every amazing location on Earth, including Africa, Patagonia, and the Marquesas.

**Why Me?**

I was shocked when Melita invited me to be one of her “expert lecturers” for an eclipse occurring two years in the future — the Great Java Sea Solar Eclipse of 2016. I explained that having never witnessed totality, I wouldn’t be very helpful to eclipse aficionados who certainly would know more than me. But she thought having an experienced astronomy educator who also happened to be an “eclipse virgin” would be a perfect addition to the trip.

Melita selected the Indonesian island of Belitung, just east of the island of Sumatra, as our eclipse-viewing site. Getting there involved a 14-hour flight from San Francisco to Hong Kong, followed by a four-hour flight to Singapore, and a two-hour flight to the city of Yogyakarta on the island of Java. Long and exhausting, the journey is typical for an eclipse trip. Total solar eclipses are visible somewhere on Earth about every 18 months, but since Earth is a pretty big place covered mostly by oceans, it’s unlikely you’ll see one in your neighborhood in your lifetime. If you decided to stay at home and wait for an eclipse to come to you, you will witness totality once every 360 years or so. So to see a total eclipse, you will likely have to travel to a very remote location.

I left San Francisco for Java with extremely low expectations. This particular solar eclipse was happening during the midst of the rainy season in Indonesia, so clear skies were unlikely. But I arrived in Java expecting the best, bringing along 4 bottles of sunscreen, UV protective clothing, numerous sun hats, and 100 pairs of eclipse viewing glasses.

**Prambanan, Borobudur, and the “No Shadow” Day**

The night we finally arrived in Java, I formally met my 40 fellow travel companions. After resting, unpacking, and settling in, we gathered together in a conference room at the hotel in Yogyakarta. Melita asked all the lecturers traveling with this group — Seth Shostak (Senior Astronomer, SETI Institute), Dennis Mammana (renowned...
astronomy writer, lecturer, and sky photographer), and me — to each give a brief introductory astronomy lecture to the group. But first, she asked everyone to introduce themselves and describe how many total eclipses we had witnessed. Annular eclipses didn't count. Many in the group had seen well over a dozen total solar eclipses — some even in the same 18 year Saros cycle! I felt like an interloper at a gathering of Eclipse Chasers Anonymous: “Hello. My name is John Smith, and I am an Eclipse-o-holic.”

Knowing nothing about witnessing eclipses, I decided to discuss something else: Astronomy and Early Civilizations. I chose this topic because during the next two days, we were visiting two ancient temples with ties to astronomy: Prambanan, a 9th-century Hindu temple, and Borobudur, a 9th-century Buddhist temple.

Prambanan’s temples and shrines (upper right) are a physical representation of the Hindu belief in the birth and death of the universe, with the largest temples in the complex dedicated to the Creator (Brahma), Preserver (Vishnu), and Destroyer (Shiva). Prambanan was abandoned in 850 AD, only 100 years after its completion. It was destroyed by earthquakes and buried in volcanic ash until its discovery in 1811 by British colonists. The very slow process of reconstruction began in 1918, but because most of the stonework had been stolen from the site, Prambanan is a shadow of its former self. Some 224 temples and shrines arranged in four concentric squares once stood at the site. Today only eight main temples, eight shrines, and two small temples remain.

Borobudur (lower right) was built in the same century as Prambanan and was also buried under volcanic ash and vegetation for more than 1,000 years. Borobudur resembles a mountain rising from the jungle floor, and as you climb it, you walk through a maze of stone corridors covered with intricately carved panels describing human consciousness — the universe Buddhists believe exists within the mind. There are three levels to Borobudur. Panels on the first level describe our baser instincts. Panels on the second level describe a higher level of existence where our selfish desires and passions are abandoned. The last level represents nirvana, the highest state of consciousness where “the self” and one’s ego are
completely abandoned. When you reach the top level of Borobudur, (right) the tall claustrophobic walls drop away and the vast sky opens up above you. You feel relief and freedom as you arrive on the top of Borobudur — a metaphor (and probably really poor substitute) for the state of nirvana.

While on my travels through Java I learned something remarkable about Borobudur. There are two smaller Buddhist temples many miles away. The three temples form a straight line and identically mirror the position of the three stars in Orion’s Belt. Even more astounding is that this trio of temples is aligned beneath the Belt stars around the time of the Vernal Equinox.

As we were still about month from the Vernal Equinox, I sadly missed witnessing that astonishing alignment. But by complete coincidence, we did visit Borobudur on March 1, one of the two “no-shadow days” occurring at this particular tropical latitude (7.61° S). A no-shadow day occurs when the Sun passes directly overhead at local solar noon. At that instant, only small puddles of shadows surround the base of objects. As exciting as no-shadow day is, there was a real problem climbing Borobudur’s steep stairs on that day — it was unbearably hot, and there was no shade anywhere. The fact that you’re climbing on stone steps that radiate the heat absorbed by the midday Sun doesn’t help matters. Despite feeling like a pizza in a clay oven, I had a lot of fun bringing out a variety of sundials (left) and other objects to help my fellow eclipse chasers and local trinket vendors fully experience the disappearance of shadows at high noon.

Volcanoes, Obsidian, and Tektites

Indonesia is part of one of the most volcanically active regions of the world. The region sits at the convergence of three major tectonic plates: the Pacific, the Eurasian, and the Indonesian. As the plates slide under each another, the crust melts and turns to magma. Volcanoes are the result of magma needing a place to escape the pressure. Really big earthquakes also happen here, such as the 8.9 magnitude quake off the coast of Sumatra in 2004. In fact, there was a 7.8 magnitude event while we were there, and the local news
didn’t even report it — ignoring it the same way a 3.0 quake is ignored in California.

Indonesia is also famous for its tektites (left), the black, glassy material resulting from meteor impacts on our planet. When a very large meteor strikes Earth, it does so at speeds reaching 150,000 mph. Depending on the angle of impact, a meteor larger than 150 feet across will make a crater 10-20 times greater than its own diameter and launch millions of tons of molten material beyond our atmosphere. As this material falls back to Earth, it is melted again and reshaped by the extreme heat of re-entry. Once cooled, these black, glassy, heavily pitted, and grooved rocks are called tektites. Tektites come in interesting shapes depending on how far they were flung from the impact site, their size, the angle of their re-entry, and whether they rotated as they fell to the ground. Their amazing shapes include spheres, buttons, teardrops, and dumbbells.

The island of Java, and particularly the island of Belitung (the location of our eclipse-observing site), is famous for its tektites. Those particular ones are the result of a meteor that landed somewhere east of the South China Sea 750,000 years ago. The impact produced a spray of tektites stretching from South China to Australia. This region is called the Australasian Strewn Field, and scientists believe it covers between 10% and 30% of the Earth’s surface. I figured that if the solar eclipse was clouded out, I could try searching the beaches of Belitung for tektites. But just in case, I bought some great tektites from a local collector.

Just When You Thought it Couldn’t Get Any Better...

From Java, we traveled to the island of Borneo to see orangutans. There we boarded two river ferries that took us deep into the jungle. Our destination was Tanjung Putting National Park and Camp Leakey, one of several orangutan sanctuaries located throughout Borneo. Conservationists in the park have set up feeding stations to sustain individuals and families of orangutans needing a little extra assistance. Several times a day, huge piles of bananas and other delicious fruits are placed on feeding platforms (above) for the scores of orangutans who wait patiently in the trees.

The feeding areas are particularly popular with females carrying newborns and tiny infants, and with younger orangutans that have recently become independent of their mothers. When a dominant female arrives at a feeding station, lower caste females and
the younger orangutans scatter, grabbing as much food as they can carry in their arms or stuff into their mouths. If you have ever seen graduate students frantically scoop up snacks at an afternoon astronomy colloquium, you get the picture.

After spending the day in the company of the orangutans, we returned to the ferries and floated down the river under a brilliant canopy of stars. The clouds had disappeared for the first time on the trip, and it gave us hope that the upcoming eclipse might be visible after all. My husband, David, turned to me and said, “Just when you think this trip can’t possibly get better, you get to see orangutans.” At that moment I looked up. Arched above my head and crossing the zenith was the Milky Way in all its glory. I saw the Large Magellanic Cloud, another experience that had been on my bucket list. I turned to David and said: “I think the trip just got better.”

The Great Java Sea Solar Eclipse of 2016
It was the morning of March 9, 2016, and the Great Java Sea Solar Eclipse was about to begin. We had made our way to the island of Belitung, located between the islands of Sumatra and Borneo and, of greatest importance, in the center of the path of totality. The slightly more than 2 minutes of totality was going to start at 7:24 am, but the disc of the Moon was scheduled to make first contact with the Sun at 6:21 am. If we wanted to experience the entire solar eclipse from the start of the partial phases, we needed to be on the buses at 4:00 am. I am not a morning person, so all I could think about was coffee.

The viewing site Melita selected for our eclipse experience was a closely guarded secret and apparently decided at the very last moment. There were at least three different solar eclipse tour groups at our hotel, and we didn’t want to give away our location and overcrowd the beach. But I also discovered eclipse chasing is a competitive sport. You want to be the cleverest person, the one who chose the location with the best viewing conditions, clearest skies, and longest viewing of totality possible. However, the care taken to select the site seemed irrelevant as we all departed the hotel under a thick blanket of clouds with only occasional breaks. I left fairly certain none of us were going to have a good eclipse day.

Our group was alone on the beach for the first 30 minutes or so before the locals started arriving in impressive numbers, mostly on scooters. Extended families appeared in large groups, and flatbed trucks drove up carrying eager children from the local schools. Few people spoke English, but all were extremely excited to see a group of Americans with their cameras and eclipse-viewing equipment lining their beaches.

I used an interpreter to help me teach the locals about the eclipse. I showed children how to use two fists to measure 20° above the horizon — the height where totality would occur should we be fortunate enough to get a break in the clouds. Most importantly, I passed out eclipse glasses to as many families as I could, making sure everyone understood to use them throughout the partial phases and remove them only during totality. (If I have any regrets,
it’s that I should have brought a lot more eclipse glasses.)

First contact was hidden behind heavy clouds and haze. It wasn’t until 20% of the Sun was eclipsed that we saw the partial phase for the first time. Then it sounded like a celestial sporting event — the crowd cheered when the Sun was visible and booed loudly when clouds obscured our view. About 80% of the way to totality, the environment changed noticeably. An odd twilight descended. For the first time in 10 days, the humid air had cooled enough that I was not frantically waving my hand fan in front of my face.

At roughly 90% totality, the ocean took on a slate-blue color I have never seen. The slow progression of darkness began to excite the crowd. It felt like a theater show was about to begin, and the house lights were being dimmed in preparation. This was as much of the Sun I have ever seen covered during the previous eclipses I’ve experienced. Everything I was about to witness would be a first for me.

Just then, the clouds thickened again. A couple of eclipse aficionados next to me started talking about where they planned to travel to see the 2017 Great American Eclipse. That’s when I really thought this eclipse would be a great disappointment. Oh well. I was privileged to see orangutans in the wild, Borobudur was incredible, and I taught astronomy to a group of really wonderful eclipse fanatics. It was going to be a memorable trip no matter what.

Then, at about 95% totality, everything changed. The heavy clouds parted revealing only a sliver of the Sun peeking out from behind the interloping Moon. Because the face of the Sun had effectively been reduced to a slit lamp, everything around me appeared in very high contrast, though exceedingly dim. The ocean in front of me looked like a black-and-white Ansel Adams photograph, with everything in sharper-than-normal focus. The sky looked oddly three dimensional, with every cloud seemingly crisper than normal.
I saw “Buddha Rays,” those wedges of light and dark sometimes seen emanating from the Sun on cloudy days. But this morning the Sun was casting rays that were extremely narrow and sharply focused. As totality began, everything suddenly went dark. It was as if the sky’s dimmer switch had been twisted to the off position in one dramatic flick of the cosmic wrist.

And So?
The clouds did actually part just long enough to see the Great Java Sea Solar Eclipse in all of its 2 minutes and 10 seconds of glory. The shimmering solar corona, the bright pink chromosphere, and the unexpectedly large prominence I saw protruding from the black disk in the sky were truly mesmerizing.

I know what you all want to know. But what was it really like for me? Was it an utterly transformative experience that has completely addicted me to chase eclipses all over the world?

It was, as many people who have witnessed totality told me, an amazing spectacle. But no, I don’t have some inexplicable urge to witness every total eclipse on the planet from now on. However, I am really glad I took the time and energy to traverse the globe to see this one. I certainly will be forever grateful to Melita Thorpe for inviting me to be a lecturer on the trip.

And guess what? She wants me along as a lecturer for her upcoming 2017 Great American Solar Eclipse tour. I didn’t fail her after all.

LINDA SHORE is the executive Director of the ASP. You can listen to her eclipse commentary (and the reactions of those around her) here; totality starts at 1:58.
A Totality 2017 Eclipse Workshop


Edited by Paul Deans

Image courtesy Hinode/XRT.
Editor’s Note: An Eclipse 2017 workshop, sponsored by the American Astronomical Society, took place in Carbondale, Illinois, on June 10 and 11, 2016. The first day’s sessions were recorded and are available for viewing on YouTube, but be warned — the entire recording is more than nine hours long! (Because of audio problems, you might want to start here with the second speaker.) Much of the second day was devoted to (non-recorded) group breakout sessions.

I was particularly interested in the discussion by Lou Mayo, who focused on what NASA doing for Eclipse 2017. So I’ve made his presentation the lead item. I’ve also included some excerpts from presentations by Charles Fulco (Talking About the Eclipse), Michael Zeiler (How Many People Live in or Near the Path of Totality? and Capitalizing on Social Media), and Fred Espenak (The Eclipse of 1842).

The content is not a verbatim transcript of the talks; it’s more like an adapted summary of five of the presentations. Any errors in the transcription are mine.

Eclipse 2017: Through the Eyes of NASA
LOU MAYO, Planetary scientist and program manager at NASA’s Goddard Spaceflight Center

NASA has a number of unique assets that we’ll bring to bear on the 2017 eclipse, as we have done during the last two decades for big celestial events. We have tremendous science, technology, and visualization resources that we can call on, we have scientists that we’re going to interview, and we’ll allow you to see the eclipse not just from the standpoint of our Moon and our Sun, but also from other moons, planets, and suns.

What We Plan to Do
We’re going to present a cross-disciplinary science theme. We’ll be talking via our social media and on our website about planetary science, heliophysics, Earth science, astrophysics, astrobiology — all the themes that are connected, in one way or another, to the study of the Sun-Earth-Moon system.

We are going to use this celestial event to emphasize NASA science mission discoveries all across the space and Earth science spectrum. So it’s kind of a hook. We’ll pull you in with the excitement and wonder of the solar eclipse, and then [for example] we’ll teach you about the detection of extrasolar planets.

One of our best assets is our people. We will be working with NASA scientists, engineers, educations, and others — interviewing them, putting them on our website, having them reach the public via social media — to give a unique perspective to the eclipse.

How We’re Going to Do All This
So how are we going to do this? NASA has an enormous suite of resources that it’s going to bring to bear on this eclipse. One of them

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http://eclipse2017.nasa.gov
is NASA Wavelength, a great resource for educators. There you'll find education products and programs for your classroom that have been vetted for scientific accuracy, currency, and pedagogy. You can even build your own list and save it for future reference.

**Eyes on the Solar System** is an interactive 3-D modeling simulator that uses real spacecraft data as well as the planetary and small-body ephemeris to model the solar system. We will be modeling the umbral shadow for this eclipse as it goes across the United States.

NASA has an extensive network of science and science education partners that we plan to use. We are coordinating with the 10 NASA Center Education Offices, having them develop education programs in concert with the eclipse. The **Night Sky Network** has more than 400 amateur astronomy clubs under their umbrella, bringing the wonders of the universe to the public. We have **Solar System Ambassadors** — teachers, amateur astronomers, and others who train on NASA content and bring it to public venues. The **NASA Museum Alliance** is a network of museums that focuses on NASA content and NASA themes. **Space Grant** is a program dominated by universities; it allows us access to the undergraduate communities.

And there's more. There are 27 groups within the NASA Science Mission Directorate that are focused on education and public outreach. These many partners will help us bring the eclipse to special populations and communities, rural, inner city, and challenged communities all across the country.

**Events and Activities**

We have big events. Perhaps you’ve heard of our **Sun-Earth Days**. Each year we wrap a fresh new thematic approach around heliophysics science while highlighting scientists, their missions, and their research. There is also **International Observe the Moon** night, which in 2017 is going to be held in proximity to the eclipse. That might sound strange, because we’re talking about the Sun since it’s going to be eclipsed. But don’t forget that the Moon is eclipsing it. So we’re going to emphasize lunar science from the ground and from spacecraft, and get people involved in doing hands-on observations — getting everyone out to look at the Moon.

NASA has a program called **Small Worlds Week**. We initially pulled this together to emphasize NASA’s investigation of comets and asteroids, but it has taken on a life of its own! So we’re going to have a **Small Worlds Week** July 10 to 14, 2017. For four days we’ll upload information about the Sun, Moon, transits, occultations, and eclipses (including eclipses seen from other planets). Then on the fifth day we’ll engage social media to let you ask us questions. We’ve done this twice so far, and it has been hugely successful.

We are also emphasizing history. We’ll indicate how eclipses have been observed and reported historically via newspaper articles, we’ll
have music with themes featuring solar eclipses, and we’ll discuss history along the 2017 path of totality from 1503 to 2024.

There will be a suite of activities that the public can do: everything from looking through the eyepiece of a telescope or just looking up at the Moon, to making some measurements and doing a little math to figure out the distance to the Moon, or figuring out how fast the umbral shadow is moving across the surface of Earth.

Of course there will be amateur astronomer observing programs. We’ve been doing this for more than a decade, first in partnership with the Astronomical League and now in partnership with the Night Sky Network. Amateur astronomers can take telescopes, look at the Moon, and identify lunar features in a Lunar ID Observing challenge. They can also photograph the eclipse and put the images on our Flickr site in a Solar Eclipse Observing challenge — and download a certificate of participation.

We’ll be recording all these events on an Events Map. People will be able to fill out a form to tell us if they’re going to make an eclipse observation, hold an eclipse party, or have an observing event at a museum, and then others will be able to find out what’s happening in their neighborhoods and go to these locations.

We are also developing a number of research-grade projects — Citizen Science — where, in partnership with NASA scientists, the public can perform publishable research. Some of the programs we’re working on include Aurorasaurus (people at higher latitudes observe the aurora, which is a by-product of solar activity), Globe (an Earth sciences project where people take measurements of temperature and light intensity during the eclipse), SunSpotter (using SOHO data to help scientists classify solar images and surface features), and Solar Corona (help scientists measure the temperature and zonal flow speeds of the solar corona). These will all be on our eclipse website.

There will be an Ask the Astronomer section on NASA’s eclipse website, so people can write in and ask questions. It will include a resource page with the most popular questions about solar eclipses, and there will also be a real-time opportunity to ask scientists questions through social media.

**Some Space Technology Options**

We also have the technology. We have many space missions that look at the universe through unique eyes. There are presently three missions that will have a chance to see the eclipse from space. One is the International Space Station. We are awaiting better ephemeris data to know exactly where the space station will be in a year — it’s not a done deal yet. The Lunar Reconnaissance Orbiter is orbiting the Moon, and our hope is that we can have it take a picture of the umbral shadow on the west coast…and then as LRO orbits the Moon, take another picture when the shadow reaches the east coast. That’s the plan, but we’ll have to see if the geometry works. Finally, the EPIC camera on the DSCOVR Mission will be able to see the eclipse from a unique vantage point beyond the Moon (as it did for the March 2016 eclipse).

Earlier I mentioned our science visualization capability. If you
go NASA’s Science Visualization Studio, you’ll find the SVS team has already posted several eclipse-related visualizations showing the eclipse from various vantage points in space. These are available for anyone to download.

Finally, coming very soon is NASA’s Eclipse 2017 website: http://eclipse2017.nasa.gov. We hope to launch it before the end of the summer. It will have all this information, science content, activities, and more.

Talking About the Eclipse

CHARLES FULCO is an astronomy teacher and a science consultant working for BOCES (New York State). He is currently traveling the US doing eclipse public educational outreach.

Whatever I tell you about totality might all go to nothing, because at my first eclipse I became a blathering idiot. I dropped film, my camera got stuck, and finally I said I’m just going to watch this thing. And that’s what you should do if you’ve never seen totality. There are plenty of people who are going to be taking good pictures. You can always access those later on the Web.

But whatever you see in photographs or videos is absolutely nothing compared to what you’ll actually see in a little more than a year. A video or photograph cannot possibly convey what the human eye can capture.

The solar corona is like a fingerprint. No two eclipses ever have the same-shaped corona (or even the same coronal brightness). Prominences are also different each time. You never get the exact same eclipse twice. And totality is never dark like a regular night. It’s sort-of twilight, but not quite.

A lot of the lesson plans I’m designing are geared for teachers out of the path of the umbra, because that’s where most people will see the eclipse. And of course even those people who do see a total eclipse will also see a partial eclipse before and after totality.

Here’s one thing you can do within the path of totality [and even if you’re not in the path but close].

The Moon’s umbral shadow cone, surrounded by its penumbral shadow, off the east coast of the US during the August 21, 2017, total solar eclipse. (NASA’s Scientific Visualization Studio)

A diagrammatic explanation of the 2017 eclipse (not to scale) showing the Moon and it’s shadow as both move from west to east. (Courtesy Michael Zeiler/GreatAmericanEclipse.com)
Have a thermometer with you and measure the temperature change every five or 10 minutes, especially as totality approaches (below).

**Talking Totality Across the Country**

Unfortunately, I’ve been running into a lot of bad science in my travels around the country. I’m not surprised, but I guess I am surprised at the persistence of bad science into the 21st century. People actually believe that the Sun produces different rays during eclipses that are blinding even if you’re looking at reflective light. That’s why principals will, a lot of times, tell the teachers to shut the doors and draw the shades — anything to keep students from looking out or going outside during the eclipse. And everyone seems to believe that students will stare at the Sun for an indefinite period of time. I tried doing that once, and you can’t do it — it hurts after a short time!

So what I’ve been doing is traveling around the country showing proper ways to view the eclipse without fear of lawsuits. Because that’s what superintendents are afraid of — they’re afraid of lawsuits. They don’t want to be sued by angry parents who think their kids are going to be blinded. This has been one of my toughest tasks, getting awareness for that going.

Of course watching it on television is perfectly safe, but it’s also the most boring way to watch one. My biggest fear is that people along the path of totality will sit at their desks during lunch — even while totality is taking place above them outside — and watch it on their computers (or on television) because the media told them to do so.

**How Many People Live in or Near the Path of Totality?**

MICHAEL ZEILER produces the maps and animated maps on GreatAmericanEclipse.com. He is a geographer employed by the leading provider of geographic information systems (GIS) software.

A question I am often asked is: How many people live within the path of totality, and how long does it take to get to the path? To help answer this question, I developed a series of maps and did some sophisticated GIS analysis, and the result is: 12.25 million Americans live within the path of totality. That’s about 3.8% of the nation. So automatically, that many people will see totality. All they have to do is go outside and look up (assuming it’s clear).

Moving away form the path of totality in reasonable distance increments, I estimate the following:

- Within 100 miles of the path, which is a fairly easy drive, 47 million people can access totality.
- Within 200 miles of the path there are approximately 88 million people, just slightly more than one-quarter of the nation. This

The drop in temperature was noticeable during the 2016 eclipse (mid-totility occurred about 9:47), and provided some welcome (albeit brief) relief from the tropical heat for those partaking in an Indonesia eclipse cruise on *Le Soleal*. [Rick Fienberg/TravelQuest International]
eclipse is so accessible to so many. Most of the eclipses that we travel to as eclipse chasers are in very remote locations, but this is an easy eclipse to reach for many non-eclipse chasers.

• Within 400 miles live some 174 million people — more than half the nation. That’s a two-day drive (one there; one back), with a one-night stay in a hotel the night before the eclipse — or bring along a tent and sleeping bags.
• Within 600 miles of totality are nearly 265 million — more than 80% of the population of the United States.
• And within 800 miles of the path are 320 million people, practically all of the United States.

Capitalizing on Social Media

MICHAEL ZEILER

This is the first major eclipse [in North America] in the social media era. If you’re doing outreach about the eclipse, and you’re not on social media, then you’re not doing it right. The importance of social media is several fold. One key point about social media is that it is the best way to reach young people and underprivileged communities. I have two young children, and I frequently take their pulse on how they get their information. I know that they never read a newspaper, and they almost never watch television. So they’re not going to get their information from broadcast media. I asked my son, how does he get his news? And he told me: YouTube.

Social media is how young people get their information. And this is a very important way for us to reach a very broad audience. So there’s Facebook, Twitter, Instagram, Snapchat, Buzzfeed, and others. A very broad part of the American population is on Facebook. As was brought up in the discussion today, Twitter is most popular during the day of an event or for something happening live.

I’d also suggest that social media has a bigger impact than the Web, which has a greater impact than broadcast media, which has a greater impact than print. Social media has become popular to the point where, for large segments of our population, it has ‘eclipsed’ all the other forms of media.

Hashtags are important. They’re used by the social platforms to help identify trends, and that’s also how people can discover your content. So it’s important to use common hashtags. Some of the ones for the 2017 eclipse include #eclipse2017, #greatamericaneclipse, #solareclipse, and probably just before the eclipse, simply #eclipse.

A final very important point about social media is that it lets us broaden our message. When you go to astronomy clubs or star parties, or check out the readership of astronomy magazines, who do

A blended image (made by Wendy Carlos) of eclipse images by Jay Pasachoff and Allison Carter. It is optimized to match a visual view over a wide dynamic range. (Courtesy Jay M. Pasachoff and Allison L. Carter, Williams College (Williamstown, Massachusetts))
you see? You see predominantly middle-aged white men. On social media, we’re reaching everybody; every type of community that’s out there. And it’s so important that we broaden our message to the entire population and not just reach the people who are already predisposed to this event.

The Eclipse of 1842

FRED ESPENAK (EclipseWise.com) is a retired NASA astrophysicist and world authority on the prediction of eclipses. He has written more than a dozen books on eclipses including his recent Eclipse Bulletin: Total Solar Eclipse of 2017 August 21.

The July 8, 1842, eclipse really put eclipses on the map. The path went through Spain, northern Italy, and into Russia. A number of astronomers of the day decided to make observations of the eclipse. One astronomer I’d like to highlight: Francis Baily, who in real life was a stockbroker and actuary.

Back in the early 19th century, astronomy was done primarily by white men of privilege. If you had the money to dabble in astronomy outside your career, that’s how science was done back then. There were very few professional astronomers or scientists. Baily traveled to northern Italy to observe the 1842 eclipse, and I think some of his observations are important to keep in mind as we think about going to see an eclipse. And so here is a transcript of some of the things he said about that eclipse. When totality began, he wrote:

“When the total obscuration took place, which was instantaneous, there was a universal shout from every observer…. I had indeed anticipated the appearance of a luminous circle around the moon during the time of total obscurity, but I did not expect, from any of the accounts of preceding eclipses that I had read, to witness so magnificent an exhibition as that which took place. It riveted my attention so effectively that I quite lost sight of the string of beads which however were not completely closed when this phenomenon first appeared.”

So it took Baily completely by surprise, this spectacular corona. A French astronomer, François Arago, traveled to the south of France to observe the same eclipse. Regarding the end of totality, he wrote:

“After an interval of solemn expectation, which lasted about two minutes, transports of joy and shouts of enthusiastic applause [greeted] the first reappearance of the rays of the Sun…. To the majority of the public, the phenomenon had arrived at its term. The other phases of the eclipse had few attentive spectators beyond the persons devoted especially to astronomical pursuits.”

And that’s true today. After totality is over, you will forget about the partial phases that follow afterwards because you will be so elevated by seeing totality itself.
The Eclipse, The Media, and Being Outside the Path

Don’t fret. Eclipse 2017 will ultimately be the media event of the season.

By Joe Rao

The total solar eclipse occurs only within the yellow path shown on this map. The yellow curves parallel to the path of totality mark the degree of maximum partial eclipse. Courtesy Michael Zeiler/GreatAmericanEclipse.com.
n recent months I’ve heard some folk express disappointment that the news media has given short shrift to next year’s “Great American Total Solar Eclipse.”

As a person who works in the news media, I can assure all of those disappointed in the coverage (or maybe I should say the lack of coverage) that Eclipse 2017 is going to be one of the big national news events in 2017. The “problem” with the news media is that they do not concentrate on the specifics of a prospective news story until less than a week before the event. Then every news-gathering agency will head toward that event like moths attracted to a flickering light.

**The Eclipse and the Media**

I have been telling everyone that in the final days leading up to the 2017 eclipse, the media will be treating this event in a manner similar to the first launch of the Space Shuttle, the Apollo 11 Moon landing, or John Glenn’s orbital flight. No question that on August 21, 2017 virtually every American will suddenly become eclipse conscious.

I can see CNN, FOX News, and MSNBC blocking out their entire news day on August 21, 2017, busily lining up anchors and camera crews all along the path of totality. And, of course, trying to entice prospective viewers to tune in to their “exclusive coverage” during the days leading up to August 21st to watch the “Eclipse of the Century!”

Isn’t that how it is played out prior to almost every eclipse? And just watch how the media will continually drive home the point that this will be the first total solar eclipse to go coast-to-coast “…in nearly one hundred years;” thus giving folks the impression that this
is the first time a total eclipse of the Sun has been visible from the United States during that same interval. Not true, of course — Hawaii in 1991 and Oregon, Idaho, Montana, and North Dakota in 1979.

As far as the American general public is concerned, I’m sure that in the days and weeks leading up to August 21st, most people will be keenly aware that: “Oh yeah, I hear there’s going to be an eclipse of the Sun this summer.” But most really will not have much incentive to view it — that is, until the “media blitz” begins during that final week. Then watch the interest spike!

And even on the very day of the eclipse, people who showed no inclination to view it will suddenly say to themselves: “Hey! Why not? Let’s drive into the eclipse zone and see what everybody has been talking about.”

In particular, watch what happens in Atlanta on eclipse morning as thousands (or maybe tens of thousands) try to get into the path of totality via Interstate 85. Normally it would take 90 minutes (to drive northeast into South Carolina and totality), but on eclipse day, who knows? It could take much, much longer.

**Activities Outside the Path**

If for whatever reason you happen to be situated outside the path of totality — perhaps you’ll be offering an outreach program for students who can’t travel to totality — make sure you observe some of the interesting effects that become evident as the eclipse progresses, such as sunlight passing through leaves and dappling the ground beneath with countless crescent images.

If you’re near the path of totality, notice the weird “counterfeit twilight” that will descend over the landscape as mid-eclipse approaches. Hold out your arm to cast a shadow — one side of your arm will be fuzzy; the other side will be sharp and clear.

The darkest period should pretty much coincide with the duration of totality. So if you’re going to be experiencing a magnitude .980 eclipse (which means you’re about 50 miles beyond the edge of the path of totality), look for the deepest twilight effect to extend across a period lasting at least 120 to 160 seconds. Certainly Venus should be evident — I glimpsed it in 1970 from New York City with an eclipse of magnitude .959.

If your observing site lacks trees with leaves, use a colander (or something similar with multiple small holes) to create images of the eclipsed Sun on the ground. [Rick Fienberg/TravelQuest International]

If you’re not in the path of totality, you must always view the eclipsed Sun through proper solar filters or eclipse glasses. [Paul Deans/TravelQuest International]
For those projecting the image of the Sun through binoculars or a telescope, or observing the eclipse with safe eclipse-viewing glasses, watch for the “pirouette of the crescent” as the waning sliver of the Sun diminishes to a certain point, then rapidly swings around 180° and begins to widen as the period of maximum eclipse passes.

An interesting experiment involving radio propagation is listening for distant AM radio stations during the eclipse. Most of us have probably heard a radio station transmitting from more than 1,000 miles away under the cover of darkness — a station that normally cannot be heard during daylight hours. The ionosphere reflects certain frequencies of radio waves, and the composition of the ionosphere at night is different than during the day because of the absence of the Sun. You can pick up some radio stations at night because the reflection characteristics of the ionosphere are better during the night.

When the Sun is nearly completely covered, atmospheric conditions resemble nighttime for a few minutes, and AM radio signals can travel much greater distances than during the day. Any 50,000-watt clear-channel radio station within or near the totality path might be heard at much greater distances during the period of maximum eclipse. Try tuning in such a station on the nights before the eclipse. Then on eclipse day, listen carefully to determine if you can hear that station around the time of maximum eclipse at your location. The station might suddenly become audible, and then after the shadow has passed by, just as suddenly disappear. Here is a list of 50,000-watt clear channel stations.

I realize veteran eclipse chasers will not want to be outside the path of totality, but for those who are, there are plenty of interesting things to look for! And maybe some of those kids who see only the partial phases will turn to their parents or teachers and say: “That was really neat! But for the next one in 2024, I want to see what happens when we’re inside the total eclipse path!”

Because in many ways, 2017 will be the incentive for 2024.

JOE RAO is one of the best-known broadcast meteorologists in the northeastern United States; his career in weather casting spans nearly four decades. He’s also an associate astronomer at the American Museum of Natural History’s Hayden Planetarium. Joe has witnessed 11 totalities.
NASA Mars Orbiters Reveal Seasonal Dust Storm Pattern

After decades of research to discern seasonal patterns in Martian dust storms from images showing the dust, the clearest pattern appears to be captured by measuring the temperature of the Red Planet’s atmosphere.

For six recent Martian years, temperature records from NASA Mars orbiters reveal a pattern of three types of large regional dust storms occurring in sequence at about the same times each year during the southern hemisphere spring and summer. Each Martian year lasts about two Earth years.

“When we look at the temperature structure instead of the visible dust, we finally see some regularity in the large dust storms,” said David Kass of NASA’s Jet Propulsion Laboratory, Pasadena, California. He is the instrument scientist for the Mars Climate Sounder on NASA’s Mars Reconnaissance Orbiter.

Dust lofted by Martian winds links directly to atmospheric temperature: The dust absorbs sunlight, so the Sun heats dusty air more than clear air. In some cases, this can be dramatic, with a difference of more than 63 Fahrenheit degrees (35 Celsius degrees) between dusty air and clear air. This heating also affects the global wind distribution, which can produce downward motion that warms the air outside the dust-heated regions. Thus, temperature observations capture both direct and indirect effects of the dust storms on the atmosphere.

Most Martian dust storms are localized, smaller than about 1,200 miles (about 2,000 kilometers) across and dissipating within a few days. Some become regional, affecting up to a third of the planet and persisting up to three weeks. A few encircle Mars, covering the southern hemisphere but not the whole planet.

MORE INFORMATION

The Hubble Space Telescope acquired this image of Mars on October 28, 2005. It reveals a dust storm (the bright patch in the middle of the planet) some 930 miles (1,500 km) long. (NASA/ESA/The Hubble Heritage Team (STScI/AURA))
New Data Compare, Contrast Pluto’s Icy Moons

NASA

A newly downlinked spectral observation of Pluto’s moon Nix from NASA’s New Horizons spacecraft provides compelling evidence that its surface is covered in water ice, similar to what the New Horizons team discovered recently for another of Pluto’s small satellites, Hydra. This new result provides further clues about the formation of Pluto’s satellite system.

With this observation by New Horizons’ LEISA — the compositional spectral imager aboard the spacecraft — mission scientists also are piecing together a more detailed picture of Pluto’s system of four small, outer moons (Styx, Nix, Kerberos, and Hydra).

The deeper spectral features on Nix are a signature of water ice that is relatively coarse-grained and pure, because the shape and depth of water-ice absorption depends on the size and purity of the icy grains on the surface.

“Pluto’s small satellites probably all formed out of the cloud of debris created by the impact of a small planet onto a young Pluto,” said New Horizons Project Scientist Hal Weaver, of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. “So we would expect them all to be made of similar material. The strong signature of water-ice absorption on the surfaces of all three satellites adds weight to this scenario. Although we didn’t collect spectra of Pluto’s two tiniest satellites, Styx and Kerberos, their high reflectivity argues that they are also likely to have water-ice surfaces.”

The difference in the depths of the water ice absorption features in the Nix and Hydra spectra raises new questions. Specifically, the science team is puzzling over why Nix and Hydra apparently have different ice textures on their surfaces, despite their similar sizes. Another mystery resulting from the Pluto flyby data is why Hydra’s surface reflectivity at visible wavelengths is higher than Nix’s, even though Nix’s surface appears to be icier, implying higher reflectivity at visible wavelengths.

MORE INFORMATION

Pluto’s moons Charon, Nix, and Hydra. Charon and Nix were imaged in color by NASA’s New Horizons spacecraft, but Hydra was not. [NASA/JHUAPL/SwRI]
Extreme trans-Neptunian Objects Lead the Way to Planet Nine

*Spanish Information and Scientific News Service (SINC)*

At the beginning of this year, astronomers K. Batygin and M. Brown from the California Institute of Technology announced that they had found evidence of the existence of a giant planet — with a mass 10 times larger than Earth’s — in the confines of the solar system. Moving in an unusually elongated orbit, the mysterious planet will take between 10,000 and 20,000 years to complete one revolution around the Sun. To arrive at this conclusion, Batygin and Brown ran computer simulations with input data based on the orbits of six extreme trans-Neptunian objects (ETNOs).

Now, however, brothers Carlos and Raúl de la Fuente Marcos, two freelance Spanish astronomers, together with Sverre J. Aarseth from the Institute of Astronomy of the University of Cambridge (UK), have considered the question the other way around: How would the orbits of these six ETNOs evolve if a Planet Nine such as the one proposed by K. Batygin and M. Brown really did exist?

“With the orbit indicated by the Caltech astronomers for Planet Nine, our calculations show that the six ETNOs, which they consider to be the Rosetta Stone in the solution to this mystery, would move in lengthy, unstable orbits,” warns Carlos de la Fuente Marcos.

“These objects would escape from the solar system in less than 1.5 billion years,” he adds, “and in the case of 2004 VN112, 2007 TG422 and 2013 RF98, they could abandon it in less than 300 million years. What is more important, their orbits would become really unstable in just 10 million years, a really short amount of time in astronomical terms.”

In any case, the statistical and numerical evidence obtained by the authors leads them to suggest that the most stable scenario is one in which there is not just one planet, but rather several more beyond Pluto, in mutual resonance.

**MORE INFORMATION**
Largest, Widest Orbit “Tatooine” Bolsters Planet Formation Theories
Institute for Astronomy, University of Hawaii

A team of astronomers announced the discovery of an unusual new transiting circumbinary planet (orbiting two suns). This planet, detected using the Kepler spacecraft, is unusual because it is both the largest such planet found to date, and has the widest orbit.

Reminiscent of the fictional planet Tatooine in Star Wars, circumbinary planets orbit two stars and have two “suns” in their skies. The new planet, Kepler-1647b, is Jupiter-sized in radius, the largest of all currently known circumbinary planets, and has an orbital period of 3.0 years, the longest of any confirmed transiting planet.

Nearly half of all Sun-like stars are members of gravitationally bound binary star systems. The most important subset of these systems are the eclipsing binary stars (stars that pass in front of each other, as seen from Earth), because they provide precise stellar masses and sizes. NASA’s Kepler Mission has observed nearly 3,000 short-period (less than 1,000 days) eclipsing binaries. Among these binaries, only nine have been found to host circumbinary planets, including Kepler-1647.

The detection of Kepler-1647b is significant for two reasons. First, its large size and large orbit are very different from those of all other known circumbinary planets. All of the previously identified Kepler circumbinary planets are Saturn-sized or smaller. Also, most of these planets tend to orbit close to their host binaries, near the so-called “critical instability radius”, where if they orbited any closer, the planet’s orbit would be dynamically unstable and the planet would be ejected from the system or crash into one of the stars.

The second significance of the discovery of Kepler-1647b is that this planet resides in the habitable zone of its host binary, a surprisingly common occurrence for circumbinary planets discovered by the Kepler space telescope.

MORE INFORMATION

Artist’s impression of the simultaneous stellar eclipse and planetary transit events on Kepler-1647. Such a double eclipse event is known as a syzygy. (Courtesy Lynette Cook)
Unpleasant Excess of Giant Planets in Star Cluster

European Southern Observatory

An international team of astronomers have found that there are far more planets of the hot Jupiter type than expected in a cluster of stars called Messier 67. This surprising result was obtained using a number of telescopes and instruments, among them the HARPS spectrograph at ESO’s La Silla Observatory in Chile. The denser environment in a cluster will cause more frequent interactions between planets and nearby stars, which may explain the excess of hot Jupiters.

A Chilean, Brazilian, and European team has spent several years collecting high-precision measurements of 88 stars in Messier 67. This open star cluster is about the same age as the Sun and it is thought that the solar system arose in a similarly dense environment.

The team used HARPS, along with other instruments, to look for the signatures of giant planets on short-period orbits, hoping to see the tell-tale “wobble” of a star caused by the presence of a massive object in a close orbit, a kind of planet known as a hot Jupiter. This hot Jupiter signature has now been found for a total of three stars in the cluster alongside earlier evidence for several other planets.

A hot Jupiter is a giant exoplanet with a mass of more than about a third of Jupiter’s mass. They are “hot” because they are orbiting close to their parent stars, as indicated by an orbital period (their “year”) that is less than ten days in duration. That is very different from the Jupiter we are familiar with in our own solar system, which has a year lasting around 12 Earth-years and is much colder than the Earth.

“We want to use an open star cluster as laboratory to explore the properties of exoplanets and theories of planet formation,” explains Roberto Saglia of the Max-Planck-Institut für extraterrestrische Physik, in Garching, Germany. “Here we have not only many stars possibly hosting planets, but also a dense environment, in which they must have formed.”

MORE INFORMATION

This artist’s impression shows a hot Jupiter-type planet orbiting close to one of the stars in the rich old star cluster Messier 67, in the constellation of Cancer. [ESO/L. Calçada]
For Second Time, LIGO Detects Gravitational Waves
Massachusetts Institute of Technology

For the second time, scientists have directly detected gravitational waves — ripples through the fabric of space-time, created by extreme, cataclysmic events in the distant universe. The team has determined that the incredibly faint ripple that eventually reached Earth was produced by two black holes colliding at half the speed of light, 1.4 billion light-years away.

The scientists detected the gravitational waves using the twin Laser Interferometer Gravitational-wave Observatory (LIGO) interferometers, located in Livingston, Louisiana, and Hanford, Washington. On Dec. 26, 2015, at 3:38 UTC, both detectors, situated more than 3,000 kilometers apart, picked up a very faint signal amid the surrounding noise.

While LIGO’s first detection, reported on Feb. 11, produced a clear peak, or “chirp,” in the data, this second signal was far subtler, generating a shallower waveform — essentially a faint squeak — that was almost buried in the data. Using advanced data analysis techniques, the team determined that indeed, the waveform signaled a gravitational wave.

The researchers calculated that the gravitational wave arose from the collision of two black holes, 14.2 and 7.5 times the mass of the Sun. The signal picked up by LIGO’s detectors encompasses the final moments before the black holes merged. For roughly the final second, while the signal was detectable, the black holes spun around each other 55 times, approaching half the speed of light, before merging in a collision that released a huge amount of energy in the form of gravitational waves, equivalent to the mass of the Sun. This cataclysm, occurring 1.4 billion years ago, produced a more massive spinning black hole that is 20.8 times the mass of the Sun.

[Editor’s Note: LIGO Caltech has prepared a science summary of the GW151226 event, written for general public.]

MORE INFORMATION
Astronomers Map 1.2 Million Galaxies to Study Properties of Dark Energy
Sloan Digital Sky Survey

Hundreds of scientists from the Sloan Digital Sky Survey III (SDSS-III) collaborated to make the largest-ever, three-dimensional map of distant galaxies. The scientists then used this map to make one of the most precise measurements yet of the dark energy currently driving the accelerated expansion of the universe.

“We have spent a decade collecting measurements of 1.2 million galaxies over one quarter of the sky to map out the structure of the universe over a volume of 650 cubic billion light-years,” says Jeremy Tinker of New York University, a co-leader of the scientific team that led this effort. “This map has allowed us to make the best measurements yet of the effects of dark energy in the expansion of the universe.”

These new measurements were carried out by the Baryon Oscillation Spectroscopic Survey (BOSS) program of SDSS-III. Shaped by a continuous tug-of-war between dark matter and dark energy, the map revealed by BOSS allows astronomers to measure the expansion rate of the universe and thus determine the amount of matter and dark energy that make up the present-day universe. A collection of papers describing these results was submitted to the Monthly Notices of the Royal Astronomical Society.

Florian Beutler of University of Portsmouth, who led two of the papers that were submitted, says “If dark energy has been driving the expansion of the universe over that time, our maps tell us that it is evolving very slowly if at all: the change is at most 20% over the past seven billion years.” The map also reveals the distinctive signature of the coherent movement of galaxies toward regions of the universe with more matter, due to the attractive force of gravity. Crucially, the observed amount of infall is explained well by the predictions of general relativity.

MORE INFORMATION
NASA’s Hubble Finds Universe Is Expanding Faster Than Expected

*Space Telescope Science Institute & NASA GSFC*

Astronomers using NASA’s Hubble Space Telescope have discovered that the universe is expanding 5% to 9% faster than expected. “This surprising finding may be an important clue to understanding those mysterious parts of the universe that make up 95% of everything and don’t emit light, such as dark energy, dark matter, and dark radiation,” said study leader and Nobel Laureate Adam Riess of the Space Telescope Science Institute and The Johns Hopkins University.

Riess’ team made the discovery by refining the universe’s current expansion rate to unprecedented accuracy, reducing the uncertainty to only 2.4%. The team made the refinements by developing innovative techniques that improved the precision of distance measurements to faraway galaxies.

These measurements are fundamental to making more precise calculations of how fast the universe expands with time, a value called the Hubble constant. The improved Hubble constant value is 73.2 kilometers per second per megaparsec. (A megaparsec equals 3.26 million light-years.)

This refined calibration presents a puzzle, however, because it does not quite match the expansion rate predicted for the universe from its trajectory seen shortly after the Big Bang. Measurements of the afterglow from the Big Bang by NASA’s Wilkinson Microwave Anisotropy Probe and the European Space Agency’s Planck satellite mission yield predictions for the Hubble constant that are 5% and 9% smaller, respectively.

MORE INFORMATION

This illustration shows the three steps astronomers used to measure the universe’s expansion. Astronomers use the HST to measure the distances to pulsating stars called Cepheid variables (left), employing parallax, a basic tool of geometry. Once the Cepheids are calibrated, astronomers examine nearby galaxies (center). They look for galaxies that contain Cepheids and Type Ia supernovae, exploding stars that flare with the same amount of brightness. Finally, they then look for Type Ia supernovae in galaxies located even farther away from Earth (right). [NASA/ESA/A. Feild (STScI) & A. Riess (STScI/JHU)]
Catherine Wolfe Bruce Gold Medal

The Astronomical Society of the Pacific (ASP) is proud to award the 2016 Catherine Wolfe Bruce Gold Medal to Dr. Andrew Fabian. He is a Professor of Astronomy at the University of Cambridge (UK) and has been the Director of the Institute of Astronomy (IoA), also in Cambridge, since 2013. Dr. Fabian obtained his PhD at the University of London in 1972, joined the IoA in 1973, and was a Royal Society Research Professor at the IoA from 1982 to 2013.

Dr. Fabian is an expert in high-energy astrophysics and has helped define the entire field of extragalactic X-ray astrophysics. He has made several fundamental contributions to our understanding of the physics of galaxy cluster cores and the X-ray emission from Active Galactic Nuclei (AGN). Dr. Fabian developed the techniques to probe the innermost regions of AGNs to determine the properties of the supermassive black holes in the centers of these galaxies.

In 2001 he was jointly awarded the Bruno Rossi Prize by the High Energy Astrophysics Division of the American Astronomical Society for the discovery, using the Advanced Satellite for Cosmology and Astrophysics, of broad iron K-lines in active galactic nuclei, which demonstrate the effects of the strong gravitational field characteristic of black holes.

Dr. Fabian has also pioneered our understanding of cooling flows of gas in massive elliptical galaxies and clusters of galaxies. He developed the theory that explains these flows, and during the past few decades has led numerous observational programs aimed at refining the theory. He has published more than 1,000 peer-reviewed scientific papers during his career — an absolutely astounding number. He has supervised more than 50 PhD students and numerous Post-Doctoral Fellows. As one of his nominators said: “Andy has changed the course of modern astrophysics, prepared a new generation to follow, and engaged the public while doing so.”

The Catherine Wolfe Bruce Gold Medal was established by Catherine Wolfe Bruce, an American philanthropist and patroness of astronomy. It is given annually by the ASP to a professional astronomer in recognition of a lifetime of outstanding achievement and contributions to astrophysics research. It was first awarded in 1898 to Simon Newcomb. Previous recipients of the Bruce Medal include Giovanni V. Schiaparelli (1902), Edwin Hubble (1938), Fred Hoyle (1970), and Vera Rubin (2003). (Here is a complete list of the Catherine Wolfe Bruce Gold Medal recipients, and a detailed bio of Dr. Fabian can also be found here.)
Robert J. Trumpler Award
The Robert J. Trumpler Award is presented to a recent recipient of a PhD degree in North America whose research is considered unusually important to astronomy. The 2016 Award is given to Dr. Rachael L. Beaton, who completed her PhD in December of 2014 at the University of Virginia. Dr. Beaton’s research has focused on “near-field cosmology,” revealing how the structure and evolution of nearby galaxies can provide insight into cosmological processes.

Her work has fundamentally contributed to our understanding of stellar populations and galaxy dynamics in the Local Group of galaxies. She is best known for her research on the Andromeda galaxy (Messier 31), including the discovery and characterization of M31’s central bar through near-infrared imaging. Dr. Beaton also led the creation of an extensive photometric catalog upon which all papers in the SPLASH (Spectroscopic and Photometric Landscape of Andromeda’s Stellar Halo) collaboration have depended.

As her more than 30 refereed publications and 1,200 citations will attest, the breadth of her work is extraordinary. Dr. Beaton also has a deep demonstrated commitment to teaching and outreach, winning numerous accolades including the “All-University Graduate Teaching Award.” Collaborator Dr. Guhathakurta (Lick Obs.) writes, “Rachael is highly intelligent, creative, motivated, and extremely hard working. She is mature well beyond her years and is a first-rate researcher.”

Klumpke-Roberts Award
Awarded to an individual or individuals who have made outstanding contributions to the public understanding and appreciation of astronomy, the Klumpke-Roberts Award for 2016 goes to Dr. Chris Impey, University Distinguished Professor of Astronomy University and Associate Dean at the University of Arizona College of Science. For more than 27 years Dr. Impey has been successfully popularizing science via his classes at the university, public talks, articles, and books. His courses have been recognized for their innovative style and approach to making science accessible to the students.

Dr. Impey has pioneered the teaching of massive open online classes (MOOCs) that reach thousands of students around the world. His YouTube channel supports astronomy video content with more than 500 subscribers, and his mentoring of undergraduate and graduate students has produced a generation of inquisitive young astronomers. In 2008, the ASP presented Dr. Impey with the Richard H. Emmons Award for excellence in college astronomy teaching.

Dr. Caitlin M. Casey (U. of Texas at Austin) writes: “Chris has dedicated much of his career to the public understanding of astronomy, not least due to his outstanding teaching record, authorship of several popularized astronomy books and introductory astronomy textbooks, [and] giant online presence, but also his infectious enthusiasm for science and dedication to sharing it with everyone.”
Las Cumbres Amateur Outreach Award
Established by Wayne Rosing and Dorothy Largay, the **Las Cumbres Amateur Outreach Award** honors outstanding educational outreach by an amateur astronomer to K-12 children and the interested lay public. The 2016 award is given to **Gena Crook** of the Von Braun Astronomical Society (VBAS) of Huntsville, Alabama, in recognition of her tireless efforts in promoting astronomy since 2001.

In addition to being a mathematics instructor at the University of Alabama Huntsville, Gena serves as the VBAS’s Director of Education and Programs and as a NASA Night Sky Network (NSN) Coordinator. She actively promotes and incorporates NSN materials into multiple presentations, including the more than 15 planetarium programs she has written. She has supported numerous VBAS outreach events in the local community such as International Observe the Moon Night at the US Space and Rocket Center, stargazing at Bridgestreet shopping center, Earth Day at Hayes Nature Preserve, and a campground at the Huntsville Madison County Botanical Garden. Gena is registered as an Astronomy Merit Badge Counselor with the Boy Scouts of America, and during the summer of 2012, she inspired young readers to go out and look at the stars by making presentations, on behalf of the VBAS, at eight regional libraries for their summer reading program.

Richard H. Emmons Award
The **Richard H. Emmons Award** — established by Jeanne and Allan Bishop in honor of her father, Richard Emmons, an astronomer with a life-long dedication to astronomy education — is awarded to an individual demonstrating outstanding achievement in the teaching of college-level introductory astronomy for non-science majors. The 2016 recipient is **Dr. Caroline Simpson**, a Professor in the Department of Physics at Florida International University (FIU) where she has taught several courses (with 150-plus students) to non-science majors each semester since 1996.

Dr. Simpson is strongly interested in reforming science education and has incorporated the latest inquiry-driven pedagogical techniques into her classes, including collaborative learning methods, learning assistants, and laboratory activities. She was one of the developers and first instructors of FIU’s Great Ideas in Science course, a multidisciplinary science course for non-majors. She laid the foundation for an interactive course and helped spread instructional reform across the sciences, a challenge that required confronting faculty and their often lecture-driven instructional stances. She also led a skeptical department into online teaching by designing and teaching two introductory astronomy courses for non-majors. Her excellence extends beyond the classroom to include being a strong advocate for students and instructional excellence at FIU.
Thomas J. Brennan Award

The Thomas J. Brennan Award is given to an individual demonstrating excellence in the teaching of astronomy at the high school level in North America. Ms. Jacqueline Barge, a science teacher and planetarium program coordinator at the Walter Payton College Preparatory High School in Chicago, Illinois, is the recipient of the 2016 Award.

Jacqueline has spent her 25-year career in the Chicago Public Schools, working with students whose experience is with a night sky that gives no hint of the unimaginable vastness beyond the glow from city streetlights. She has brought the universe into the hands of countless numbers of urban students by revealing how to explore space using databases, imaging software, remote telescopes, apps, and other tools. It is easy to see her excellence as she motivates a group of students to do extracurricular research throughout the year and then takes them to the Jet Propulsion Lab in a culmination project with NASA/IPAC.

Whether with a visiting class of elementary students, teaching in one of her high school classes, or participating in a teacher training workshop, she always has wisdom to pass on. One of her supporters writes: “I have often thought that Jackie is so exceptional that she could work anywhere — a suburban district, a museum, or in a beautiful natural setting where the sky is clear. Apart from her considerable talents, I genuinely admire Jackie for the dedication as a public school teacher in a district in need of exceptional teachers.”

Maria and Eric Muhlmann Award

The Maria and Eric Muhlmann Award, for recent significant observational results made possible by innovative advances in astronomical instrumentation, software, or observational infrastructure, is awarded jointly in 2016 to Professor Ian McLean (left, University of California Los Angeles) and Professor Charles ‘Chuck’ Steidel (right, California Institute of Technology) for their roles as Co-Principal Investigators on the Multi-Object Spectrometer for Infrared Exploration imager (MOSFIRE), a revolutionary low-resolution, multi-object, near-infrared spectrograph on the Keck 10-meter telescope on Mauna Kea, Hawai‘i.

MOSFIRE is ideally suited for studying galaxy clusters at moderate redshift, and the initial results of large surveys using this instrument are fundamentally changing our understanding of these galaxy clusters. The increase in the number of objects that can be studied simultaneously, and the significantly improved sensitivity over previous instruments, is transformative for the study of faint, moderate-redshift galaxies.

Professor McLean was responsible for the design and construction of the instrument in his laboratory at UCLA. Professor Steidel provided much of the scientific motivation and case for MOSFIRE
and is using it to lead the Keck Baryonic Structure Survey, which is designed to investigate the interchange of baryons between galaxies and the intergalactic medium in the redshift range 1.8<z<3.0, corresponding to the peak of cosmic star formation.

MOSFIRE also enables other investigations of the stellar populations, dust content, and physical conditions within the interstellar medium of typical star-forming galaxies at these epochs.

Mars “Explorers Wanted” Posters
Mars Needs You! In the future, Mars will need all kinds of explorers, farmers, surveyors, teachers, and more. NASA has commissioned a set of eight posters illustrating, in a somewhat campy fashion, some of the jobs that will need filling when Mars exploration by humans really gets going. Download the posters from NASA’s Mars Exploration site.

NEW MEMBERS — The ASP thanks all those who recently renewed their membership, and welcomes new members who joined between April 1 and June 30, 2016.

Individual
Michael Brady, Santee, CA
PJ Cabrera, San Francisco, CA
J. Donald Cline, Greensboro, NC
James Finn, Santa Rosa, CA
Robert Fitzgerald, Tucson, AZ
David Kensiski, Benicia, CA
Evan Lavie, San Francisco, CA
Michael Lawson, Chester, VA
Danial Lee, Kluang, Malaysia
Rick Linden, Oninda, CA,
Natti Pierce-Thomson, Gilroy, CA
Alma Rico, Oakland, CA
Wolf Witt, Mountain View, CA
Ted Vredenburg, Cheyenne, WY

Senior
Barbara Alcalá, Pioneer, CA
John Carter, Prescott Valley, AZ
Michael Dougherty, Melbourne, Victoria, Australia
Barbara Gex, Oakland, CA
Joseph Montani, Tucson, AZ
Robert Pettengill, Austin, TX

Student
Kayla Capitan, Charleston, SC
Ava & Ella Damascus, Wood Dale, IL

Technical
Joseph Bevelacqua, Richland, WA
Arturo García Álvarez, Los Angeles, CA
Betty Pui Shan, Hong Kong, China
Makoto Watanbe, Okayama, Japan
sky sights

by Paul Deans

The Skies of August
Any description of August's sky sights would not be complete without mention of the Perseid meteor shower. This annual display is likely one of the most regularly watched celestial events, precisely because it's regular. Of course, it also helps that the Perseids peak during summer when it's warm, and casual observers are more likely to be willing to head outside for a while.

This year the Perseids peak from the late evening on the 11th to dawn on the 12th (Thursday night to Friday morning). Even though there's a first quarter Moon the night prior, it will set around 1:00 am local time on the 12th. So you'll have to stay up late to be moonlight free and have a chance to spot the 60-plus meteors per hour that often grace the summer sky at this time. Still, the evening of the 11th is not a total waste; begin watching once the radiant (the point from which the meteors appear to stream or radiate) in Perseus clears the horizon (right).

Try not to miss this year's shower, because it will be better than the one in 2017 — not because the Perseids will be weaker, but because next year the Moon, just past full, will be in the sky most of the peak night, and moonlight washes out the fainter Perseids.

The good news is that there are three planets in the dusk sky this month. The bad news is that you'll need a very low, flat, and clear western horizon to see any of them. Venus, the brightest, sets about 50 minutes after the Sun all month. If you can spot this world in the sunset glow, you might be able to find the others.

At the start of the month, the thin lunar crescent will help. On the 4th, look about 2° (or eight lunar diameters) to the upper right of the 2-day-old Moon. If you're lucky, you'll spot dim Mercury. The next night look about 2° to the upper left of the now 3-day-old crescent, and you should be able to find Jupiter.

During the rest of the month, Mercury rarely gets closer than 8° to Venus. But Jupiter goes charging right in. On the 27th Venus and Jupiter have a particularly close conjunction. They're a mere 0.2° apart...
but low in the west, setting about 55 minutes after the Sun. They will
be a splendid sight in binoculars or a small telescope, but only briefly.
Ultimately, Venus remains in the west for several months to come, but
Jupiter vanishes into the solar glare, reemerging at dawn in October.

Mars and Saturn shine in the south-southwest, setting around
midnight at the start of the month and by 11:00 pm at month’s
end. Both are in Scorpius. On the 23rd and 24th, Mars passes
about 4° below Saturn and 2° above Antares. Mars is significantly
brighter, but how much redder than Antares (which means “like
Mars”) is the red planet? On the 11th Mars shines far below the
Moon, while Saturn glows to Luna’s lower left.

The Skies of September
An annular eclipse of the Sun occurs on the 1st. Annularity is vis-
ible along a narrow path from the south Atlantic Ocean through cen-
tral Africa (including Gabon, the Democratic Republic of the Congo,
and Tanzania), crosses northern Madagascar, and ends in the Indian
Ocean short of Australia. Greatest duration (3 minutes 5 seconds)
occurs in eastern Tanzania. The partial eclipse covers almost all
of Africa; more information is available here. There is also a deep
penumbral eclipse of the Moon on the 16th, visible from Europe,
Africa, Asia, and Australia; details can be found here.

In the west after sunset, Venus clings to the horizon while Jupiter
vanishes. On the 2nd, Jupiter sits immediately to the right of the
36-hour-old Moon, but good luck seeing them because both set
a mere 45 minutes after the Sun. One day later, Venus is to the far
lower right of the now-easier-to-spot lunar crescent.

Mars and Saturn glow in the south-southwest as darkness falls.
On the 8th the Saturn sits some 4° below the first quarter Moon; the
next night Mars is twice that separation below the Moon.

Meanwhile, Mercury pops up in the dawn sky toward the end of
the month. It’s actually a good opportunity to spot this elusive little planet.
On the 29th it sits some 4° above a very thin crescent in the morning
twilight; both rise in the east about 80 minutes before the Sun.

Attention telescope users. On the evenings of the 26th to 30th
inclusive, Mars is within a mere 2° of M8, the Lagoon Nebula. This is
sure to be a fine telescopic sight; astrophotographers take note. But
both set by 10:30, so don’t delay your observing session.

The Autumnal Equinox occurs on September 22nd at 10:21 am
Eastern (6:21 am Pacific); autumn begins in the Northern Hemisphere.

The Skies of October
For Northern Hemisphere observers, this is a poor apparition of
Venus. For much of its time in the autumn dusk sky, this bright
planet slinks along the horizon, barely putting in a post-sunset
appearance. For example, on the 1st it sets a mere 75 minutes after
the Sun; on the 31st it sets not quite two hours after Sol. And even
at month’s end, it’s only 15° above the horizon at sunset — hardly
a blazingly obvious evening star. Things do improve slightly during
the first few months of 2017. And once you spot Venus, it’s bright
and easy to find on future evenings, even if it’s low. On the 3rd, the
crescent Moon hangs just above Venus.
If you follow the Moon this month, it’ll guide you to Saturn and Mars. On the 5th and 6th, look in the southwest after dusk for Saturn to appear to the Moon’s left and lower right respectively. Then on the 7th and 8th, spot Mars far to the lower left and lower right, respectively, of the nearly first quarter Moon.

During October, if you keep watch as dusk fades, you’ll see Venus and Saturn moving closer to each other. On the 27th, the dim ringed world sits less than 4° directly above brilliant Venus, while Antares, if you can find it in the twilight glow, is less than 4° below Venus. The two planets hang together for the remainder of the month.

In the dawn sky, Mercury starts the month as it ended September; rising about an hour before the Sun. But it’s retreating quickly, and by mid-month it’s becoming difficult to pick out of the twilight glow. However, even as Mercury falls back, Jupiter rises. On the 11th, about 30 minutes before sunrise, see if you can spot dim Mercury beside bright Jupiter. They’re less than 1° apart, but both are very low in the east. Then at dawn on the 28th, look for Jupiter beautifully placed just above the thin crescent Moon.

During the morning hours of the 18th, the Moon occults bright Aldebaran (in Taurus) for observers across much of the eastern and southeastern US. Here is a PDF map showing where the occultation can be seen; the October issue of Sky & Telescope and Astronomy magazines should have more details.

Autumn Astronomy Day occurs Saturday October 8; check the Clubs & Events page on the NASA/ASP Night Sky Network for events in your area. International Observe the Moon night is also on the 8th.

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**Star Charts**

If you’d like a star chart to help you explore the naked-eye night sky, you have several options: purchase a star wheel (planisphere) or planetarium software, download a PDF showing the sky this month, find an online star chart, or locate an app for your tablet or smartphone.

**PDF Star Charts.** Skymaps produces a well-done chart that goes beyond a mere monthly star chart. It includes a list of monthly highlights and observable celestial objects. The downside: each month is available only at the very end of the previous month. Another nice star chart is available from Orion Telescopes and Binoculars; you can download it one month in advance. If you’d like simple star charts that don’t show the planets, a set of 12 is available from the Canada Science and Technology Museum.

**Online Star Charts.** Sky View Café gives you control over the chart’s date, time, and location, plus a few other options. But the chart names only a few bright stars, doesn’t identify the constellations, and the printout of the resulting chart is poor. The star chart created on the Tau Astronomy Club website offers fewer options but a better printout. But it lists no star names and the stars are color coded based on their spectral type.

**Apps For Tablets and Smart Phones.** SkySafari 4 ($2.99 for the basic version; available for iPhone, iPad, and iPod touch; now available for Android) is a very well done star chart app and is the one I use consistently. TheSky by Software Bisque is one of the most popular planetarium programs out there, and is now available for the iPad and iPhone. If ASP stargazers have a favorite night sky app, regardless of the device, I’d like to hear about it.

— P.D.
Transit of Mercury

In case you missed it, this is a still from a movie of the transit of Mercury on May 9, 2016, as seen by the HMI telescope on Solar Dynamics Observatory. Here is a movie of the transit, so slow it almost seems that it's in real time. Also available are transit movies at two other wavelengths. [Courtesy NASA's Scientific Visualization Studio.]